A MICROPROBE TECHNIQUE FOR MEASURING SLOW CRACK VELOCITIES IN BRITTLE SOLIDS

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The measurement of slow crack velocities in highly brittle solids is of importance as a means for quantifying the kinetics of fundamental bond-rupture processes. Such measurements are not easy to make, however, for the very property which characterises true brittleness, that of low resistance to fracture, does not lend itself to the introduction and control of a well-defined crack. Perhaps the most successful technique in current use is the double-cantilever method developed by Wiederhorn and co-workers [1,2].

In this note we report on a new technique which has its roots in indentation testing, with all the attendant advantages of simplicity, economy, control, and reproducibility fully preserved. More specifically, the technique is an adaptation of the so-called Hertzian fracture test, in which a critically loaded ball indenter forms a truncated cone crack in the specimen. In previous investigations, where the emphasis has been on the rapid accumulation of general strength data, interest has focussed on the crack history from surface flaw to cone initiation [3-5]. With the present crack velocity tests, however, the need to locate the crack tip at all stages leads us to turn our attention to the subsequent growth of the fully developed cone.

The scheme is outlined in Fig. 1. A WC sphere, with a machined flat to maintain a constant contact circle, is loaded onto a specimen until a cone crack forms. The stable cone can then be made to extend further into the specimen, either by increasing the indenter load or by introducing a reactive environment into the crack system. In our preliminary experiments on soda-lime glass in water environments progress of the crack tip is followed by photographic means. The entire identation operation is carried out within an environmental chamber [6].

The basis for a fracture mechanics description of the crack system is an equation derived by Roesler [7] for a *true* cone,

$$G = K(E)P^2/R^3 \qquad (1)$$

where G is the crack-extension force, K(E) a constant involving elastic moduli, P the indenter load and R the base radius of the cone. Calibration runs on glass specimens in vacuum, in which the crack may be considered to remain in a state of stable equilibrium, serve to test the validity of (1): under these conditions the crack is predicted to increase with load according to

$$P_c^2/R_c^3 = G_c/K(E) = \text{const} \qquad (G = G_c) \qquad (2)$$

Fig. 2 shows that this equation is reasonably well obeyed for $R_c >> R_o$.

On admitting water environment to the chamber the cracks continue to extend, at a slow rate, without further increase in load. Eliminating K(E) from (1) and (2), we have

$$G/G_c = (R_c/R)^3 \quad \text{(P const)} \tag{3}$$

Thus a normalized crack-extension force may be readily evaluated for any subcritical configuration $R>R_c$. At the same point an average crack velocity

$$v_c = (\Delta R/\cos\,\alpha)/\Delta t \tag{4}$$

may be recorded between successive photographic frames. Fig. 3 shows $v_c(G)$ obtained in this way for runs in liquid water and several pressures of water vapour. These data are in essential agreement with those reported by other workers, using different techniques, for the glass-water system [1,2,8].

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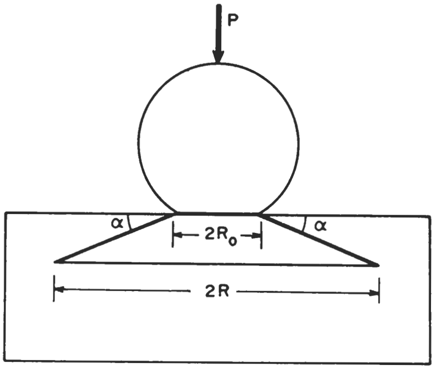

Fig. 1 Schematic of cone crack test. Indenter is WC sphere with 2 mm diam. flat. Specimen is glass slab 25 mm thick. (All data in following figures taken from single specimen).

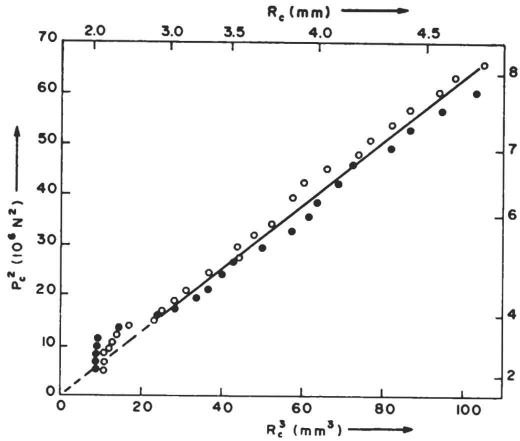

Fig. 2 Plot of P_c^2 vs P_c^3 for tests on soda-lime glass in vacuum (<10^{-4} Nm^{-2}). Data for two cracks.

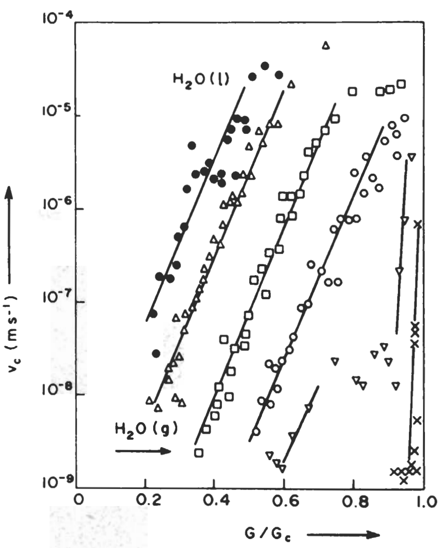

Fig. 3 Plot of crack velocity as function of normalized crack-extension force for tests on soda-lime glass in water environments: closed symbol denotes liquid; open symbol denotes vapour, pressure (Nm^{-2}) 2×10^3 (Δ), 1×10^2 (□), 10 (O), 1×10^{-2} (∇), 1×10^{-4} (×). Each set of data from different crack.